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Growth of Site Trees and Stand Structure in Mixed Stands of Pacific Silver Fir and Western Hemlock

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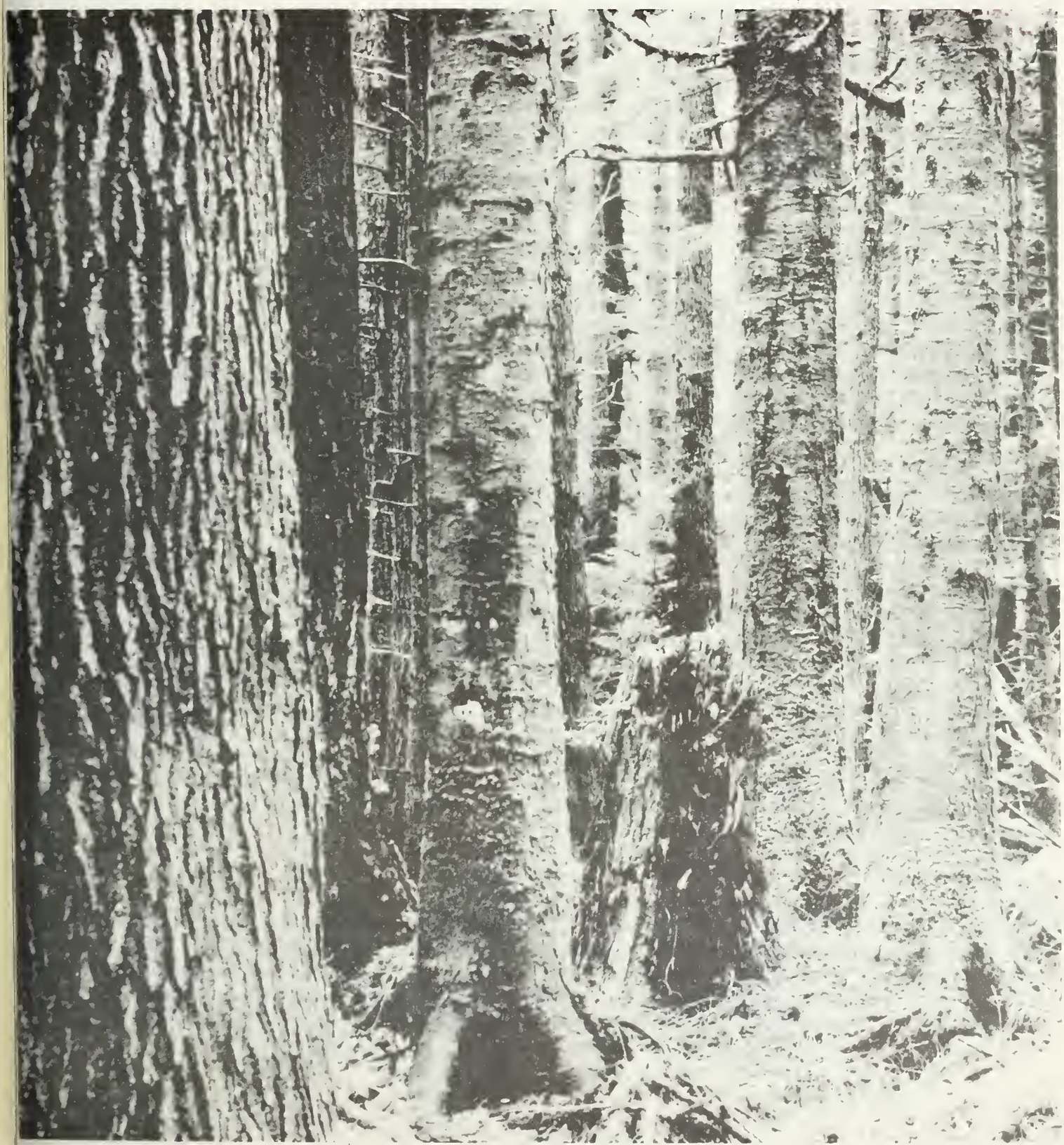

Authors

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Abstract

Murray, Marshall D.; Leonard, Peggy C. 1990. Growth of site trees and stand structure in mixed stands of Pacific silver fir and western hemlock. Res. Pap. PNW-RP-431. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 12 p.

Height and diameter growth of Pacific silver fir (*Abies amabilis* Dougl. ex Forbes) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) site trees, as well as overall stand structure on 0.15-acre plots, were analyzed in mixed stands 43 to 57 years old in breast height age at six locations in western Washington. These mixed stands have produced volumes of 9,160 to 20,200 cubic feet per acre. Early height and diameter growth of hemlock site trees was greater than that of silver fir. After 30 to 45 years of growth, the predicted site index of silver fir was 1 to 2 feet greater than that of hemlock at four locations and 11 feet greater than that of hemlock at one location. Hemlock site trees were larger in diameter at breast height (d.b.h.) than silver fir 30 years before present, but since that time the rate of d.b.h. growth has decreased for both species, with less decrease for silver fir than for hemlock. Silver fir and hemlock were present in all crown classes, and both species had the same range in d.b.h. at three locations. Silver fir generally had, however, a greater proportion of larger stems than did hemlock. At five locations, silver fir had fewer stems per acre than hemlock, but this true fir contributed more volume per acre in proportion to number of stems than hemlock did. Silver fir was an important component of these mixed stands and should be treated similarly to hemlock during precommercial and commercial thinning.

Keywords: Mixed stands, stand structure, site trees (growth), Pacific silver fir, *Abies amabilis*, western hemlock, *Tsuga heterophylla*.

Summary

Pacific silver fir and western hemlock are common associates in western Washington. Mixed stands of these two species are valuable for timber production, watershed protection, wildlife, and recreation, but little is known of their management. The purpose of this study was to compare growth of silver fir and hemlock site trees and stand structure at six locations in western Washington. Early height growth of hemlock site trees was greater than that of silver fir, but after 30 to 45 years of growth, the predicted site index (height of site trees at breast height age 50 years) of silver fir was 1 to 2 feet greater than that of hemlock at four locations and 11 feet greater than hemlock at one location. On the highest hemlock site sampled, silver fir site index was 5 feet less than that of hemlock. Early diameter at breast height (d.b.h.) growth of hemlock site trees was also greater than that of silver fir, but silver fir has maintained rapid d.b.h. growth longer than hemlock. Both species were present in all crown classes at the six locations. Silver fir had a larger percentage of trees in the upper crown canopy than hemlock at four unburned locations and was equal to hemlock at another unburned location. Hemlock had a larger proportion of upper canopy trees at a burned location. At three locations, both species had the same range of d.b.h. classes and had trees in each of the classes. Three other locations had larger trees and more variation, but the two species did not have trees in every d.b.h. class. Silver fir generally had a greater proportion of larger stems than hemlock and thus contributed more cubic-foot volume per acre in proportion to number of stems than hemlock. Advance regeneration on unburned areas and a long period of rapid height growth after an initial slow phase allowed silver fir to compete with the initially faster growing hemlock. During thinning of mixed stands, silver fir should be treated similarly to hemlock.

Introduction

Pacific silver fir (*Abies amabilis* Dougl. ex Forbes) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) are common associates in western Washington. In the northern Cascade Range, these two conifers are found together at low to middle elevations on slopes and in valleys; south of Snoqualmie Pass, mixtures of silver fir and hemlock occur on higher peaks and ridges (Franklin 1965). These two species coexist throughout the western and central Olympic Mountains; on the west side of the Olympics, silver fir occurs with hemlock near sea level (Fonda and Bliss 1969). The highest peaks and ridges and the head of major drainages in the Coast Range south of the Olympic Mountains also contain mixtures of silver fir and hemlock (Murray and Treat 1980).

Mixed stands of silver fir and hemlock are valuable for timber production, watershed protection, wildlife, and recreation; consequently, management of these stands is important. Few data are available, however, on yield, stand structure, and relative growth of the two species when grown together.

Yield tables and site indices have been developed for stands of western hemlock (Barnes 1962; Wiley 1978a, 1978b), and much is known about the management of this species (Atkinson and Zasoski 1976). In contrast to hemlock, silver fir has not been actively managed in the past because of the belief that it was slow growing and susceptible to attack by balsam woolly aphid (*Adelges piceae* Ratzeburg). But the balsam woolly aphid is confined thermally to southern coastal British Columbia and some low-elevation, high-quality sites in western Washington (Husted and Korelus 1982, Mitchell 1966). Interest in the management of silver fir has increased in the last decade (Boecksteigel 1982, Deer 1982, Husted and Korelus 1982).

The objective of this study was to compare height and diameter growth of individual silver fir and hemlock site trees as well as overall stand structure in mixed stands 45 to 60 years old at breast height age in western Washington.

Methods

Study Areas

Study areas were located throughout western Washington (fig. 1), including each of the true fir-hemlock ecological provinces defined by Franklin (1965). These ecological provinces, based on differences in geology, physiography, climate, and soils, provide a stratification for management and research purposes. Two study areas were located in the Mount Baker province, two in the Mount Rainier province, and one each in the Coast Range province and the lowlands west of the Olympic Mountains. Elevations were moderate and ranged from 550 to 3,100 feet. Soils were various mixes of volcanic and glacial materials, thereby illustrating the diversity of soil types on which these two species can be found (table 1). All stands were clearcut except for Forks, which originated after blowdown. Wolf Point was burned after logging; the four other logged stands were unburned.

Hemlock seeded in after disturbance at each location. The abundant, regular seed production of hemlock results in a high rate of seedling establishment after disturbance. Although silver fir produces less seed more irregularly than hemlock (Scott and others 1976), some silver fir also seeded in at each location; at Wolf Point, the burned location, this was the only source of silver fir regeneration.

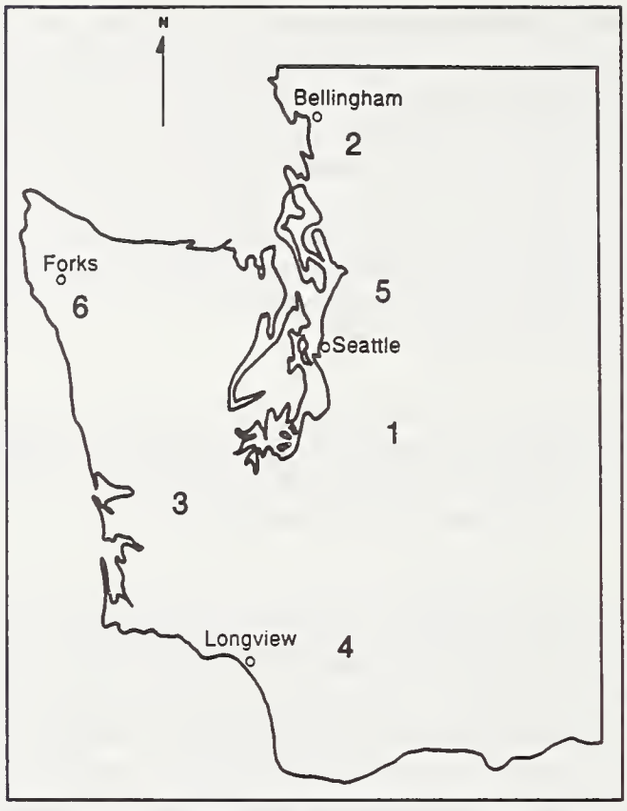


Figure 1—Locations of Pacific silver fir-western hemlock study plots in western Washington.

Table 1—Soil and topographic characteristics for 6 mixed Pacific silver fir-western hemlock stands in western Washington

Location		Soil parent material[a]	Elevation	Aspect	Slope
Number	Name				
			Feet		*Percent*
1	Grass Mountain	Volcanic ash and andesitic rock colluvium	3,100	NW	15
2	Mount Josephine	Volcanic ash and colluvium over phyllite	2,500	N	50
3	Blue Mountain	Colluvium from basalt	1,500	S	25
4	Wolf Point	Colluvium from andesite and tuff	2,100	N	15
5	Echo Lake	Volcanic ash and till	1,900	NE	40
6	Forks	Loess and ablation till overlying very compact lodgement till	550	N	7

[a] From State Soil Survey Reports, 1983, Washington State Department of Natural Resources, Forest Land Management Division, Olympia, WA.

At the unburned locations, advance regeneration silver fir survived after logging and was present before hemlock seedlings became established. Advance regeneration silver fir were identified by a cluster of branch stubs on the bole at the point of release. Some hemlock advance regeneration was identified at the low-elevation Forks location but not at the Cascade locations. The lack of hemlock advance regeneration at higher elevations is not unusual; conditions at higher elevations favor survival of silver fir seedlings over those of hemlock. Under mature canopies in the lower *Abies amabilis* zone of the Washington Cascades, silver fir reproduction is common on the forest floor, whereas hemlock reproduction is found only on downed logs, stumps, and windthrow mounds (Long 1976). Silver fir can germinate immediately after snowmelt and can produce seedlings having a sturdy tap root. In contrast to silver fir, hemlock germination is delayed 3 to 4 weeks after snowmelt, and the resultant seedlings are small and limber with shallow roots. During the growing season, upper organic layers of the forest floor become dry, thereby subjecting hemlock to severe moisture stress. Silver fir seedlings, on the other hand, are deeper rooted and not as severely affected (Kotar 1972, Scott and others 1976, Thornburgh 1969).

Sampling Procedures

A 0.15-acre sample plot was established in a well-stocked part of the stand that included both silver fir and hemlock at each location. All live trees in the plot were numbered, measured at breast height, and classified by crown class. Both hemlock and silver fir site indices (Hoyer and Herman 1989, Wiley 1978b) were determined at each location. Hemlock site trees (trees of dominant and codominant crown class) are defined as the 10 trees of greatest diameter at breast height (d.b.h.) in a group of 50 adjacent trees (Wiley 1978b). Site trees were selected from the 10 largest trees by d.b.h. from 50 hemlock listed on the tally sheet. Five of the six plots did not contain 50 hemlock, which led to tallying additional trees outside but immediately adjacent to the plot. Six final site trees were chosen from the 10 selected trees; these six included the largest tree, the smallest tree, and a range of d.b.h. sizes in between. To make comparisons among trees of comparable diameters for both species, six silver fir site trees with d.b.h.'s similar to those of the hemlock site trees were also selected. If six silver fir site trees were not found on the plot, trees were selected outside but immediately adjacent to the plot. The six site trees of both species were examined visually; another tree of similar d.b.h. was chosen to replace any originally selected tree that was forked or damaged. Age at breast height of the site trees was determined by an increment borer. Any site tree whose increment core at breast height showed evidence of suppression was rejected, and another tree of similar d.b.h. was substituted.

Radial increment for each site tree was averaged from three increment cores taken at 120-degree intervals around the stem at breast height. Age at 21 feet above ground (the height of two sections of climbing ladder) of three site trees of each species was determined with an increment borer.

Total height was measured on each plot for an additional four trees of each species throughout a range of d.b.h.'s less than site tree size. These four trees were combined with the six site trees to develop a local volume equation for each species at each location. Cubic volume of the silver fir height sample trees was taken from table 78 of the volume tables for Pacific Northwest trees (Johnson 1955). Standard cubic-foot volume tables for hemlock in Washington and Oregon were used to obtain cubic volume of the hemlock height sample trees (Wiley and others 1978).

Results and Discussion

Stand Characteristics

Site index at breast height age 50 years ranged from 90 to 111 feet for hemlock and from 91 to 107 feet for silver fir (table 2). Breast height ages ranged from 42 to 57 years and total stocking ranged from 362 to 600 stems per acre. Total volume on the 0.15-acre plots varied considerably and ranged from 9,160 to 20,200 cubic feet per acre. Although the single plots did not demonstrate the variation within the entire stand at each location, they did provide an indication of the volume in well-stocked mixed stands. With the variation that typically exists in true fir-hemlock stands, these values may be higher than the average for the stand.

Hemlock had more stems per acre then silver fir at all locations except Wolf Point. Anomalously, silver fir had more stems than hemlock at this burned location; we do not know why. A seed source and timing of seed crops in favor of silver fir may account for more silver fir at this location.

Table 2—Average site index, height of site trees, breast height age, density, and yield data for 6 mixed Pacific silver fir-western hemlock stands in western Washington

Characteristics and species	Unit of measure	Location					
		Grass Mountain	Mount Josephine	Blue Mountain	Wolf Point	Echo Lake	Forks
Site index:[a]							
Western hemlock	Feet	90	96	98	105	107	111
Pacific silver fir	Feet	91	107	100	107	106	106
Average height site trees:							
Western hemlock	Feet	81	95	88	98	100	121
Pacific silver fir	Feet	84	111	91	96	106	116
Average breast height age:							
Western hemlock	Years	43	49	43	45	45	57
Pacific silver fir	Years	44	51	43	42	50	55
Stems per acre:							
Pacific silver fir	Number	198	100	204	204	145	66
Western hemlock	Number	317	277	396	139	278	310
All species	Number	515	409[b]	600	362[c]	436[d]	376
Quadratic mean stand diameter:							
Pacific silver fir	Inches	12.2	12.4	10.2	11.7	12.0	14.7
Western hemlock	Inches	10.9	8.5	9.3	16.1	10.6	14.1
All species	Inches	11.4	10.1	9.6	13.3	11.1	14.2
Volume per acre:							
Pacific silver fir	Cubic feet	6,440	4,270	4,700	6,250	5,470	3,980
Western hemlock	Cubic feet	6,300	3,570	6,550	7,640	6,950	16,220
All species	Cubic feet	12,740	9,160[b]	11,250	14,930[c]	12,640[d]	20,200

[a] Index age 50 years at breast height.
[b] Includes 32 Douglas-fir per acre.
[c] Includes 19 Douglas-fir per acre.
[d] Includes 13 western redcedar per acre.

Silver fir at all locations contributed more total cubic-foot volume per acre in proportion to total number of stems then hemlock. At Grass Mountain, for example, 38 percent of the total stems per acre were silver fir, but they contributed 51 percent of the total cubic-foot volume per acre. Except for Wolf Point, the quadratic mean stand diameter of the silver fir was larger than that for hemlock at all locations; the range was from 0.6 inch larger at Forks to 3.9 inches larger at Mount Josephine.

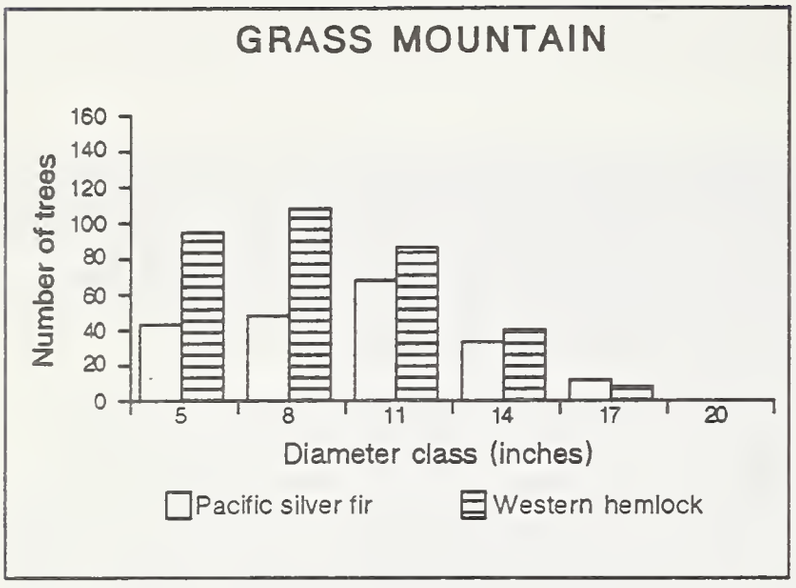
Stand Structure

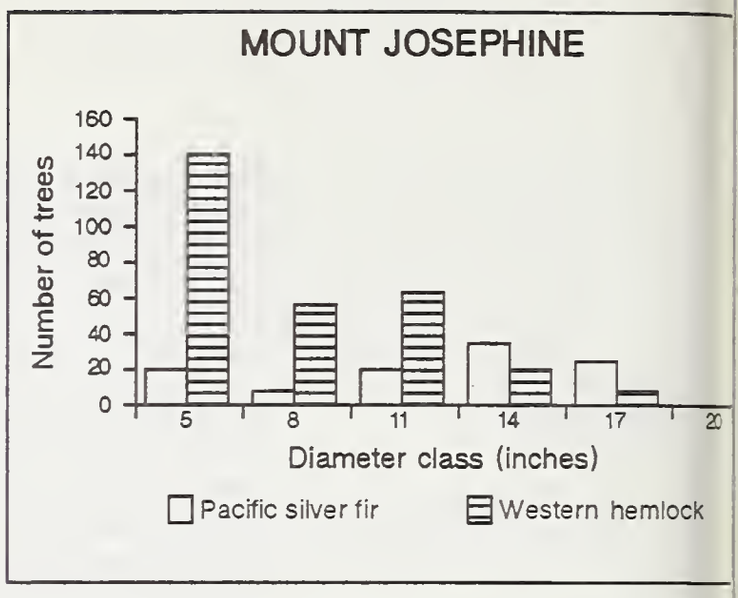
The distribution of trees by d.b.h. class was different for each location, but some common patterns among the six study areas were evident. The number of trees in each d.b.h. class is shown in figure 2. At Grass Mountain, Mount Josephine, and Blue Mountain, silver fir and hemlock had the same range of d.b.h.'s (5 to 17 inches), and both species had trees in each of the five d.b.h. classes. Wolf Point, Echo Lake, and Forks had larger d.b.h.'s and more variation that the other three locations; d.b.h. ranged from 5 to 20 inches, but trees were absent in some d.b.h. classes for both species.

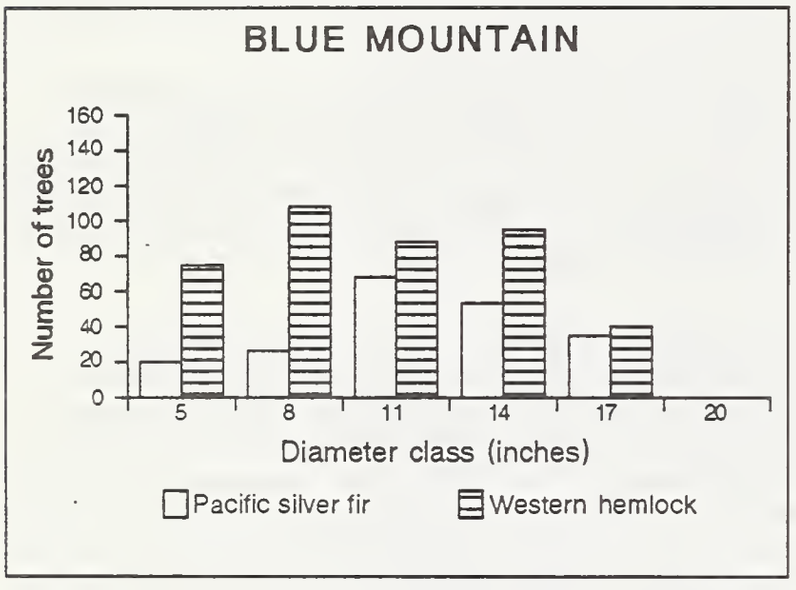
Silver fir generally produced a greater proportion of larger stems than hemlock did. Hemlock on all locations except Wolf Point had more trees in the smaller d.b.h. classes than did silver fir. The number of hemlock 8 inches d.b.h. and smaller ranged from 206 percent greater than silver fir at Grass Mountain to 757 percent greater at Forks. The larger number of small-sized hemlock reduced the quadratic mean stand d.b.h. of this species relative to that of silver fir.

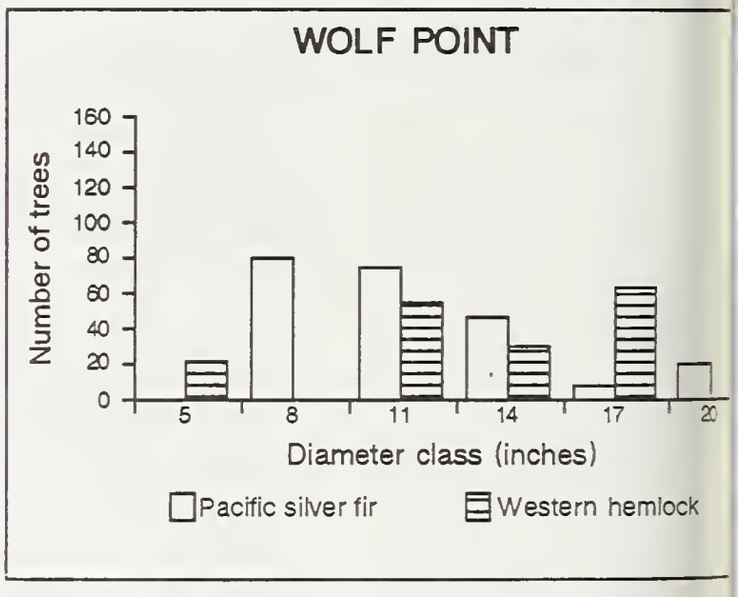
Both species at the six study locations were present in all four crown classes—dominant, codominant, intermediate and suppressed (fig. 3). At Grass Mountain, Mount Josephine, and Blue Mountain, silver fir had a larger percentage of trees in the upper crown classes (dominants and codominants); that is, 15, 54, and 15 percent more than hemlock for the three locations, respectively. An average of 69 percent of all hemlock for these three locations were in the lower crown classes (intermediate and suppressed), but an average of only 41 percent of the silver fir were in the lower crown canopy. The percentage of silver fir in the upper crown classes was substantially less than that for hemlock at Wolf Point and equal to that for hemlock at Echo Lake. The Forks stand had 70 percent of both silver fir and hemlock in the upper crown classes.

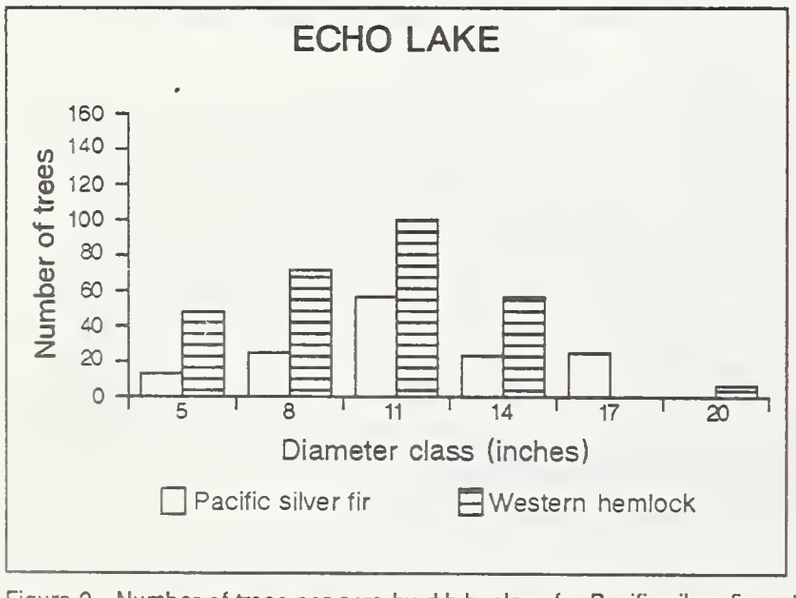
On the unburned areas, advance regeneration silver fir became a part of the upper crown canopy. Johnson and Zingg (1968) also found that advance regeneration silver fir less than 5 feet tall and up to 88 years old that were released by clearcutting became dominants in a mixed stand of hemlock and other species. It was evident that burning has influenced the stand structure at Wolf Point. In contrast to the unburned areas, advance regeneration silver fir at Wolf Point was destroyed. Some of the postlogging regeneration of silver fir became part of the upper crown canopy at this location but the faster growing hemlock produced more dominant and codominant trees than did silver fir. The Forks stand, which had originated from blowdown and contained both silver fir and hemlock advance regeneration, had an equal percentage of both species in the upper crown classes.











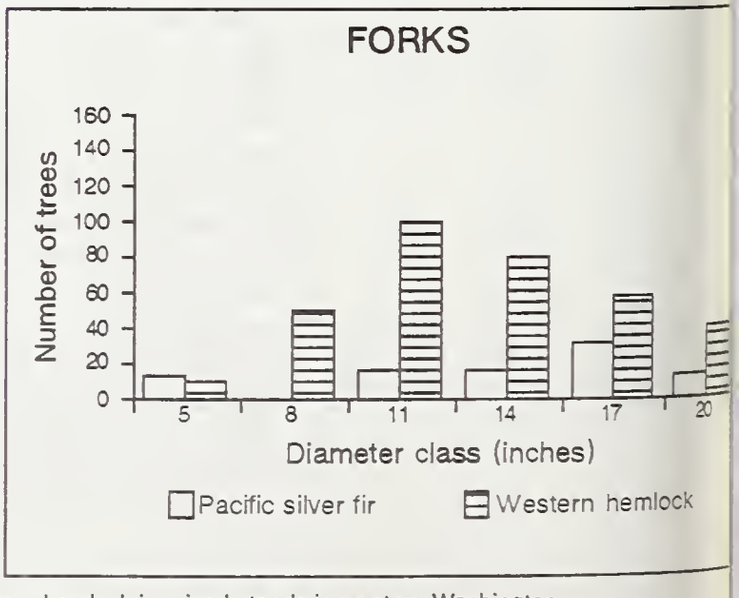
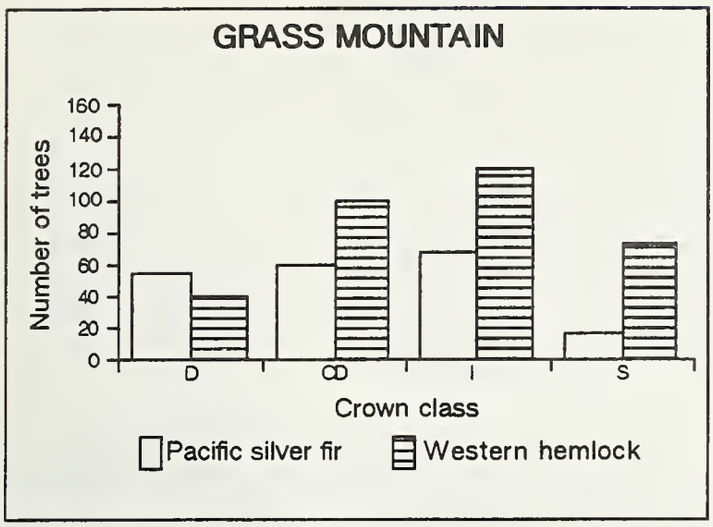
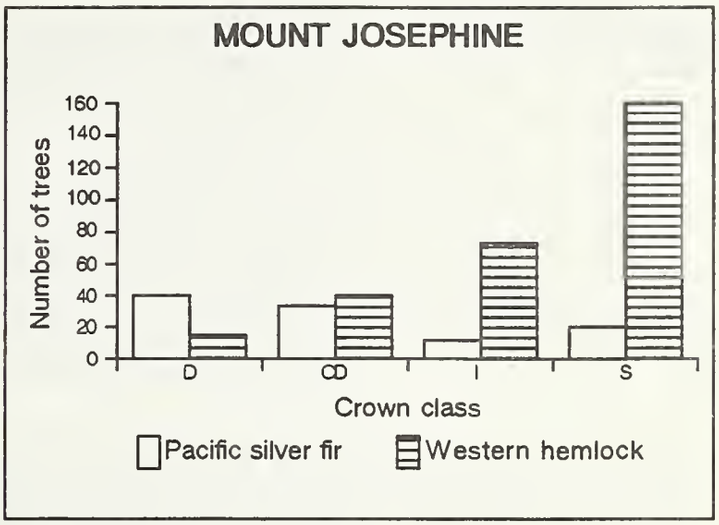
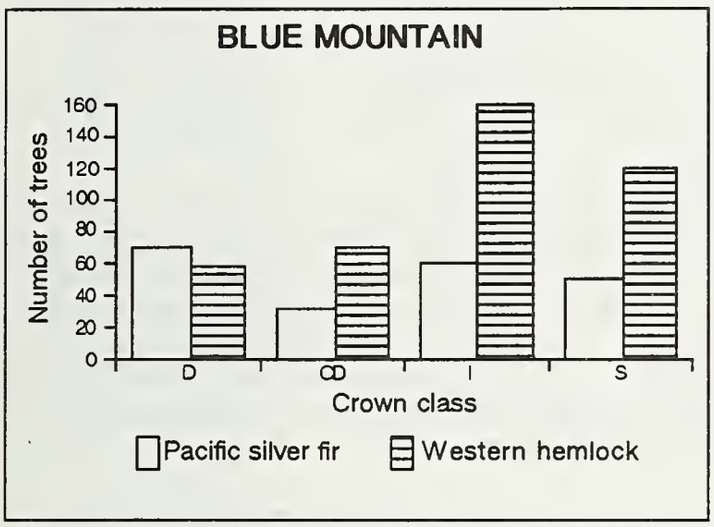
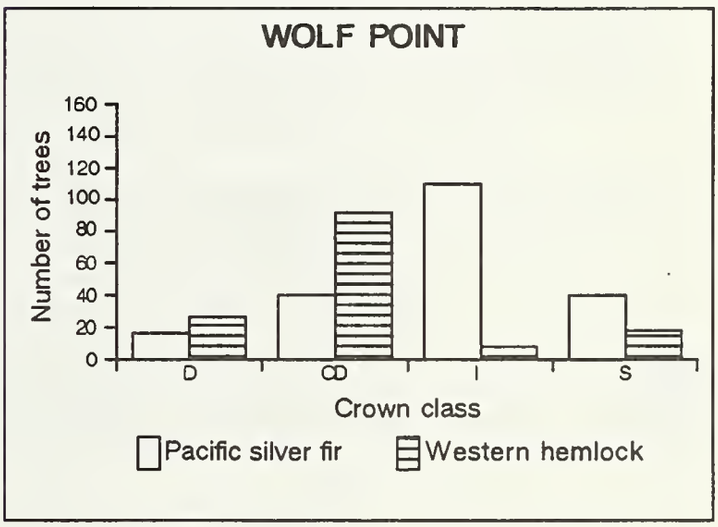


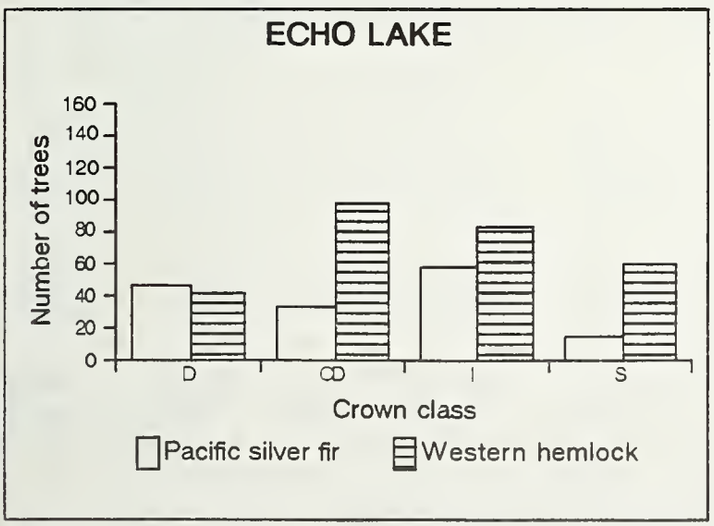
Figure 2—Number of trees per acre by d.b.h. class for Pacific silver fir and western hemlock in mixed stands in western Washington.











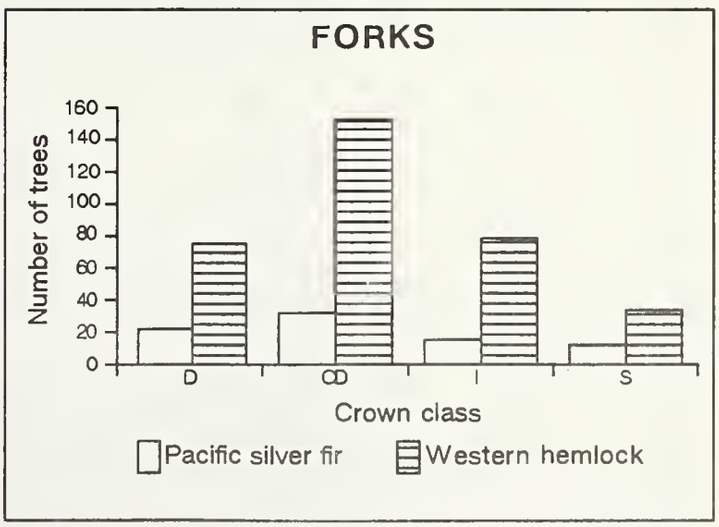


Figure 3—Number of trees per acre by crown class (D = dominant, CD = codominant, I = intermediate, S = suppressed) for Pacific silver fir and western hemlock in mixed stands in western Washington.

Comparison of Site Trees

Height

Hemlock site trees required 6 to 10 years to grow from 4.5 feet to 21 feet in height compared to 9 to 13 years for silver fir (table 3). It took both species 10 years to reach 21 feet in height at Mount Josephine. At Grass Mountain, Mount Josephine, and Echo Lake, the silver fir advance regeneration reached 4.5 feet sooner than hemlock reached this height. The initial height advantage that silver fir advance regeneration had over hemlock postlogging regeneration was only temporary. Hemlock regeneration establishing after logging will generally outgrow released silver fir advance regeneration in the lower *Abies amabilis* zone of the western Washington Cascades (Scott and others 1976). Although the silver fir at Grass Mountain and Echo Lake reached 4.5 feet before the hemlock reached this height, the more rapidly growing hemlock attained a height of 21 feet before the silver fir.

At Blue Mountain, both species reached 4.5 feet at the same time, but again the faster growing hemlock reached a height of 21 feet before the silver fir. In contrast to Grass Mountain, Blue Mountain, and Echo Lake, the advance regeneration silver fir at Mount Josephine maintained its lead over hemlock and reached a height of 21 feet before the hemlock. At Wolf Point, the burned location without advance regeneration silver fir, the faster growing hemlock reached both 4.5 feet and 21 feet before the silver fir reached these heights. Hemlock also reached 4.5 feet and 21 feet before the silver fir reached these heights at the Forks location. The Forks stand, which originated from blowdown, contained both silver fir and hemlock advance regeneration.

The difference in site index of the two species was small at four of the six locations. Site index of silver fir was 1 to 2 feet greater than that of hemlock at Grass Mountain, Blue Mountain, Wolf Point, and Echo Lake (table 2). With an 11-foot difference at Mount Josephine, silver fir site index at this location was substantially greater than that for hemlock. At Mount Josephine, as mentioned above, silver fir reached both heights (4.5 feet and 21 feet) before the hemlock and has maintained a lead over the hemlock. At Forks, the location with the highest hemlock site index, the estimated site index of silver fir was 5 feet less than that of hemlock.

Table 3—Calendar year in which Pacific silver fir and western hemlock site trees reached a height of 4.5 (breast height) and 21 feet, respectively, and number of years required to grow from breast height to a height of 21 feet (in parentheses)

Height and species	Location					
	Grass Mountain	Mount Josephine	Blue Mountain	Wolf Point	Echo Lake	Forks
4.5 feet:						
Pacific silver fir	1938	1931	1939	1942	1932	1928
Western hemlock	1939	1933	1939	1937	1937	1925
21 feet:						
Pacific silver fir	1947(9)	1941(10)	1952(13)	1951(9)	1943(11)	1937(9)
Western hemlock	1945(6)	1943(10)	1948(9)	1943(6)	1944(7)	1931(6)

These comparisons show that at five locations, silver fir reached a height of 21 feet after the hemlock reached this height; but after 30 to 45 years of subsequent growth, the site index (predicted height at breast height age 50 years) of silver fir was similar to that of hemlock at four locations. Silver fir, in common with other true firs, has slow early height growth, but after this slow phase a long period of rapid height growth can be expected (Harrington and Murray 1982). Stem analysis studies in 60- to 250-year-old true fir-hemlock stands in the Oregon and southern Washington Cascades show that free-growing silver fir are initially shorter than hemlock, but after 100 years silver fir become taller than the hemlock (Herman 1967). This indicates that silver fir overtakes hemlock in height sometime before 100 years. A study of three silver fir-hemlock stands in the northern Washington Cascades showed that individual dominant hemlock have faster initial height growth but eventually are surpassed in height by silver fir in all three site qualities sampled (Grant 1980).

Diameter

The silver fir site trees were chosen for present diameters similar to those of the hemlock site trees. The d.b.h. of silver fir site trees for all locations averaged 16.4 inches compared to 16.3 inches for hemlock (table 4). Thirty years in the past, however, the hemlock site trees averaged about 22 percent larger in d.b.h. than the silver fir (6.2 inches for silver fir and 7.6 inches for hemlock). The hemlock site trees were larger than those of silver fir in the past, but silver fir has maintained rapid d.b.h. growth longer and has caught up with the hemlock. Diameter growth of both species diminished over time but the decrease was less for silver fir than for hemlock.

Table 4—Average present d.b.h. and average past diameter increment (inside bark) of Pacific silver fir and western hemlock site trees

Location	Species[a]	Present average d.b.h.	30-year past average d.b.h.[b]	10-year diameter increment			Total 30-year diameter increment
				1st decade	2d decade	3d decade	
		Inches					
Grass Mountain	PSF	15.9	6.3	4.0	3.2	2.4	9.6
	WH	15.8	6.6	4.2	3.2	1.8	9.2
Mount Josephine	PSF	15.1	6.7	3.0	3.0	2.4	8.4
	WH	15.2	7.8	3.2	2.4	1.8	7.4
Blue Mountain	PSF	13.8	3.4	3.4	3.6	3.4	10.4
	WH	13.5	4.9	3.4	2.6	2.6	8.6
Wolf Point	PSF	19.7	5.3	6.4	4.8	3.2	14.4
	WH	19.6	8.2	5.2	3.8	2.4	11.4
Echo Lake	PSF	15.8	7.0	3.2	3.2	2.4	8.8
	WH	15.3	7.1	3.4	3.0	1.8	8.2
Forks	PSF	18.1	8.5	3.6	3.4	2.6	9.6
	WH	18.3	11.1	3.0	2.4	1.8	7.2

[a] PSF = Pacific silver fir; WH = western hemlock.
[b] Present average d.b.h. minus 30-year diameter increment.

Average d.b.h. increment of silver fir site trees ranged from 0.2 inch less than hemlock at Grass Mountain, Mount Josephine, and Echo Lake to 1.2 inches more than hemlock at Wolf Point during the first 10 years of the 30-year period. During the second 10 years, d.b.h. growth of silver fir site trees was equal to or greater than that of hemlock at all locations. By the third decade, silver fir were averaging 0.27 inch per year d.b.h. increment compared to 0.20 inch per year for hemlock.

Conclusions and Management Implications

Our study suggests that mixed stands of Pacific silver fir and western hemlock have substantial management potential in upper slope forests of western Washington.

1. Mixed stands of silver fir and hemlock 43 to 57 years old in breast height age produced volumes of 9,160 to 20,200 cubic feet per acre on the 0.15-acre plots used. Silver fir was an important component of these stands, contributing more cubic volume in proportion to number of stems than hemlock did.

2. The mixed stands at all six locations had silver fir and hemlock present in all crown classes. At the five unburned locations, silver fir had a larger percentage of trees in the upper crown classes than hemlock at four locations and was equal to hemlock at one location. Hemlock had a larger proportion of upper canopy trees at the burned location than the silver fir. At three locations, both species had the same range of d.b.h. classes and had trees in each of the classes. Three other locations had larger trees and more variation but did not have trees in every d.b.h. class.

3. Advance regeneration silver fir on unburned areas became part of the upper crown canopy. This advance regeneration is worth managing in future mixed silver fir-hemlock stands.

4. Present average d.b.h. of silver fir and hemlock site trees was similar at each location, but patterns of past d.b.h. growth were different. Hemlock 30 years before present were larger in d.b.h. than silver fir, but since that time the rate of d.b.h. growth has decreased for both species with less decrease for silver fir than for hemlock.

5. Height growth of silver fir site trees from a height of 4.5 feet to 21 feet was slower than that of hemlock at five locations; but after 35 to 45 years of growth, the predicted site index of silver fir was 1 to 2 feet greater than that of hemlock site index at four of the six locations. At one location, silver fir site index was 11 feet greater than that of hemlock.

6. During precommercial thinning of mixed stands, taller hemlock should not necessarily be favored over shorter silver fir. A long period of rapid height and diameter growth after an early slow phase allows silver fir to enhance its position relative to initially faster growing hemlock.

7. There are opportunities to manipulate mixed silver fir-hemlock stands through commercial thinning. The similar height of site trees suggests that these two species may be treated similarly in commercial thinning prescriptions for rotations of 6 decades or less. At rotations longer than 60 years, silver fir can surpass hemlock in height. For longer rotations it may be desirable to reduce the proportion of hemlock in thinning and leave the silver fir to grow for future harvest.

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Height and diameter growth of Pacific silver fir (*Abies amabilis* Dougl. ex Forbes) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) site trees, as well as overall stand structure on 0.15-acre plots, were analyzed in mixed stands 43 to 57 years old in breast height age at six locations in western Washington. These mixed stands have produced volumes of 9,160 to 20,200 cubic feet per acre. Early height and diameter growth of hemlock site trees was greater than that of silver fir. After 30 to 45 years of growth, the predicted site index of silver fir was 1 to 2 feet greater than that of hemlock at four locations and 11 feet greater than that of hemlock at one location. Hemlock site trees were larger in diameter at breast height (d.b.h.) than silver fir 30 years before present, but since that time the rate of d.b.h. growth has decreased for both species, with less decrease for silver fir than for hemlock. Silver fir and hemlock were present in all crown classes, and both species had the same range in d.b.h. at three locations. Silver fir generally had, however, a greater proportion of larger stems than did hemlock. At five locations, silver fir had fewer stems per acre than hemlock, but this true fir contributed more volume per acre in proportion to number of stems than hemlock did. Silver fir was an important component of these mixed stands and should be treated similarly to hemlock during precommercial and commercial thinning.

Keywords: Mixed stands, stand structure, site trees (growth), Pacific silver fir, *Abies amabilis*, western hemlock, *Tsuga heterophylla*.

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